

Soil Characterization Lab Analysis Protocol



Welcome

Introduction

Protocols

Learning Activities

Appendix

Soil Characterization Field Measurements

Purpose

To determine the bulk density of the soil

To determine the soil particle size distribution

To measure soil pH

To determine soil fertility by measuring the amounts of nitrate nitrogen, phosphorus, and potassium (N, P, K) in the soil

Overview

In the classroom/laboratory, students will dry the bulk density samples in an oven, weigh them, sieve them to remove rocks, and determine the weight and volume of the rocks. The sieved bulk density or other samples will be used to determine the particle size distribution, the soil pH, and the soil fertility (N, P, K).

Time

For drying soil samples, allow at least 10 hours for drying at 95 - 105 ° C, 24 hours for drying at 75 - 95 ° C, or two days for air drying (no classroom time is involved).

Preparation of dispersing solution needed prior to class - 10 minutes

Dispersing step for Particle Size Distribution procedure, sieving dry samples and completing the bulk density measurement - one class period

2 and 12 minute measurements for Particle Size Distribution, and measurements of Soil pH and Soil Fertility - one class period

Final Particle Size Distribution measurement, clean up, and review of all the data - one class period

Level

Soil Fertility (N, P, K) — Intermediate and Advanced.

Other measurements — All

Frequency

Once for each horizon

Three samples for each horizon

Key Concepts

Volume

Density

Bulk density

pH of soil

Soil fertility (N, P, K)

Soil nutrients

Chemical reactions

Specific gravity

Particle size distribution

Texture

Supernatant

Skills

Handling samples

Sieving samples

Recording data

Manipulating scientific equipment

Observing color

Pipetting

Measuring pH, specific gravity, and soil fertility

Determining relative nutrient content

Using a hydrometer

Materials and Tools

For Recording Data During All Measurements:

Bulk Density Data Work Sheet

Particle Size Distribution Data Work Sheet

pH Data Work Sheet

Soil Fertility Data Work Sheet

For Drying and Sieving Samples:

Newspapers or plastic plates

#10 sieve (2 mm mesh openings)



Liter-size bags, jars, or containers for storing soil samples

Balance

Rubber gloves

For Bulk Density

Drying oven or microwave

100 mL graduated cylinder to determine volume of rocks

Balance

For Particle Size Distribution:

Rolling Pin, hammer, or other utensil for crushing peds and separating particles

500 mL clear plastic graduated cylinder

Hydrometer

Thermometer (needs to have a smooth surface without a cover so that soil and water do not get trapped)

Spoon or other utensil to transfer soil

Spoon or stirring rod for stirring soil

Dispersing solution (50 g Sodium Hexametaphosphate/liter or non-sudsing powdered detergent containing sodium and phosphate)

250 mL or larger beaker

Squirt bottle for washing soil out of beaker

Stop watch or a clock with a second hand
Plastic Wrap or other material to cover top of cylinder during shaking

1 L bottle for dispersing solution

For pH:

Three 100 mL-beakers

Balance

pH paper, pen, or meter

Glass stirrer or spoon

Distilled water

100 mL-graduated cylinder to measure distilled water

For Soil Fertility:

Distilled water

Soil Fertility Kit with reagents to measure N, P, and K

Teaspoon

Cup or test tube rack to hold tubes

For Disposing of Soil:

Buckets or other large water tight containers

Preparation

Calibration of pH meter or pen

Prerequisites

Soil Characterization Field Measurement

How to Measure Bulk Density and Prepare Samples for Other Lab Analyses

Bulk Density

1. Dry the samples in their containers following the directions given for drying samples in the *Gravimetric Soil Moisture Protocol*.
2. Weigh each dry bulk density sample in its container and record this dry weight on the Bulk Density Data Work Sheet.
3. Rocks don't hold water or store nutrients, so they don't contribute to the bulk density of soil.

To determine the density of any rocks that are in a sample use the following procedure (if there are no rocks in your sample, skip this part):

3.1 Place a large piece of paper (such as newspaper) on a table and put the #10 (2 mm openings) sieve on top of it. Pour one sample into the sieve.

3.2 Put on rubber gloves to avoid contaminating your sample with acids from your skin.

3.3 Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve as this may bend the mesh openings. Rocks will

not pass through the mesh and will stay on top of the sieve. If no sieve is available, carefully remove the rocks by hand.

3.4 Save the sieved soil from each sample for the other lab analyses.

3.5 Weigh the rocks, and record this weight on the Bulk Density Data Work Sheet.

3.6 Place 30 mL of water in a 100 mL graduated cylinder, and without spilling, add the rocks to the water. Read the level of the water after all the rocks have been added and record this value and the original volume of water on the Bulk Density Data Work Sheet.

As you add the rocks, if the volume of the water comes close to 100 mL, record the increase in volume, empty the cylinder and repeat the procedure for the remaining rocks. In this case, you must calculate and record the sum of the water volumes with the rocks and the sum of the water volumes without the rocks.

Making Sense of the Data

When you are done, the following should have been recorded on your Bulk Density Data Work Sheet and reported to the GLOBE Student Data Server using the Bulk Density Data Entry Sheet:

- the volume of the soil can (mL) (For the pit or surface sampling method)
- the weight of the soil can (g) (For the pit or surface sampling method)
- the diameter of the hole (cm) (For the auger method)

- the top and bottom depth of the hole (cm) (for the auger method)
- the weight of the container (g) (for the auger method)
- the weight of the moist soil and container (g) (only needed if you wish to calculate soil water content)
- the weight of the dry soil and container (g)
- the weight of the rocks (g)
- the volume (or sum of the volumes) of the water added to the graduated cylinder before rocks are added (mL)
- the volume (or sum of the volumes) of the water after rocks have been added (mL)

To calculate soil water content:

In doing the bulk density measurements, if you measured the weight of the moist soil and container you have obtained all the information needed to determine the soil water content of your sample. If you wish to know the soil water content, follow the procedures for this calculation given in the *Gravimetric Soil Moisture Protocol*. These soil water content values are not reported to GLOBE; they are only for student practice and added insight.

If you are not measuring bulk density

Prepare the samples for the lab analyses.

1. Place a large piece of paper (such as newspaper) on a table.
2. Put the #10 (2 mm openings) sieve on top of it.

The bulk density of the soil material (in units of g/cm³) can now be calculated for each sample by:

$$\text{Bulk density} = \frac{\text{dry weight} - \text{container weight} - \text{weight of rocks}}{\text{container or hole volume} - \text{volume of rocks}}$$

$$\text{Hole volume} = \pi \times \left[\frac{\text{hole diameter}}{2} \right]^2 \times [\text{bottom depth of hole} - \text{top depth of hole}]$$

$$\text{Volume of rocks} = \text{volume of water and rocks} - \text{volume of water before rocks were added}$$

If you had to measure the volume of rocks in more than one batch, add the volumes calculated for each batch to get the total volume of rocks.



3. Pour the sample into the #10 sieve. Put on rubber gloves so the acids in your skin don't contaminate the soil pH measurement.
4. Carefully push the dried soil material through the mesh onto the paper. Do not force the soil through the sieve or you may bend the wire mesh openings. Rocks will not pass through the mesh and will stay on top of the sieve. Remove the rocks (and other pieces of debris) from the sieve and discard. If no sieve is available, carefully remove the rocks and debris by hand.
5. Transfer the rock-free, dry soil from the paper under the sieve into new, clean, dry plastic bags or containers.
6. Seal the containers, and label them the same way that they were labeled in the field (horizon name, top and bottom horizon depth, date, site name, site location). This is the soil that will be used for the other lab analyses.
7. Store these samples in a safe, dry place until they are used.

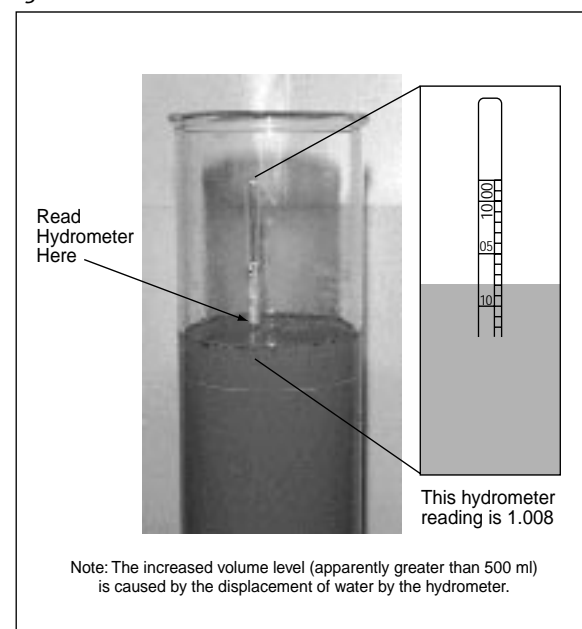
How to Measure Soil Particle Size Distribution

Repeat this measurement three times for each horizon, and record all sets of data on the Particle-Size Distribution Data Work Sheet.

1. Prepare the dispersing solution by mixing 50 g of Sodium Hexametaphosphate (or other material as indicated above), in 1 L of distilled water. Dissolve all of the solid material by stirring the mixture.
2. After drying and sieving the soil samples, use a rolling pin, mortar and pestle, or hammer to break up any large particles that might still be present.
3. Weigh 25 grams of dried, sieved soil and pour it into a 250 mL or larger beaker. Pour 100 mL of the dispersing solution and about 50 mL of distilled water into the beaker. Stir vigorously with a spoon or stirring rod for at least one minute. Be sure the soil is thoroughly mixed and does not stick to the bottom of the beaker. Do not spill any of the soil suspension.

4. When the soil and dispersing solution are thoroughly mixed, rinse any soil left on the stirrer into the beaker with the rest of the mixture. Set the beaker aside in a safe place and allow it to sit for about 24 hours (the sample can be left to mix with the dispersing solution over the weekend as well).
5. While the suspension is sitting, put a meter stick or other ruler in the cylinder and measure the distance between the 500 mL mark and the bottom of the cylinder. Also read the temperature at which your hydrometer has been calibrated (such as 15.6° C or 20° C). This number will be found somewhere on the hydrometer. Record both on the Particle Size Distribution Data Work Sheet.
6. After roughly 24 hours (or during the same class period the next school day), stir the suspension in the beaker again, and pour it into a 500 mL graduated cylinder.
7. Using a squirt bottle, rinse out the beaker with distilled water, and add this to the soil mixture in the cylinder.
8. Add enough distilled water to fill the cylinder to the 500 mL mark.
9. Securely cover the top of the cylinder using plastic wrap or another secure cover.

Figure SOIL-P-8



10. Mix vigorously by rotating the covered cylinder hand-over-hand at least 10 times. Be sure the soil is thoroughly mixed in the solution and does not stick to the bottom of the cylinder. Also, try not to let any of the soil suspension leak out the top.
11. Gently set the cylinder down in a safe place, and immediately begin timing with a stop watch or clock with a second hand.
12. Record the time that the cylinder was set down to the second.
13. After 1½ minutes, carefully lower (do not drop) the hydrometer into the cylinder and allow it to float in the soil suspension. Steady the hydrometer to suppress its bobbing up and down.
14. Exactly 2 minutes after the cylinder was set down, read the line on the hydrometer that is closest to the surface of the soil suspension. See Figure SOIL-P-8.
Note: Read the hydrometer for the Soil Particle Size Distribution protocol the same way that is read for the *Salinity Protocol*.
15. Remove the hydrometer, rinse it, dry it, and gently put it down in a safe place.
16. Suspend the thermometer in the soil suspension in the cylinder for about 1 minute.
17. At the end of 1 minute, remove the thermometer from the suspension, read the temperature, and record the result on the Data Work Sheet.
18. Rinse the thermometer off and dry it.
19. Allow the cylinder to sit safely without being disturbed.
20. Take another hydrometer measurement in the undisturbed cylinder at 12 minutes. Place the hydrometer carefully in the suspension about 30 seconds before taking the reading to allow it to settle.
21. Take and record another temperature reading for the suspension.
22. Rinse the hydrometer and thermometer off when they have been removed from the suspension and dry them.
23. Record these results on the Particle Size Distribution Data Work Sheet.

24. Leave the cylinder undisturbed for 24 hours (or until the beginning of the same class period the next day). Note: this time period is critical and should not be significantly longer than 24 hours.
25. Take another hydrometer and temperature reading.
26. Record the results on the Data Work Sheet.
27. Discard the soil suspension by pouring it into a special pail, and spill the contents outside in a place for discarding soil materials. DO NOT pour the suspension down the sink!
28. Carefully rinse and dry the hydrometer, thermometer, beakers, and cylinders, and repeat the above steps 2 more times for the same horizon so that you have a total of 3 sets of results for this horizon.

Note: This measurement involves considerable waiting time and must be done for three samples from each horizon in the soil profile. The number of days required to complete the set of measurements depends on the amount of equipment available. After a sample is mixed with dispersing solution and water initially, it should stand for a day before proceeding to do the measurement, and after the first two measurements, the sample sits undisturbed for 24 hours more. If your soil profile has five horizons, this task must be done 15 times. If only one 500 mL cylinder is available, the measurement of all the samples must be spread out over many days. Having multiple 500 mL cylinders would allow you to accelerate this process. One hydrometer should be adequate for use with at least three cylinders if the starting times of the settling are staggered by about three minutes. However, a single 500 mL cylinder and hydrometer are adequate for use in the *Hydrology Investigation Salinity Protocol*, and if your students will be doing the soil characterization only a few times spread over several school years, then the same cylinder and hydrometer can be reused and the particle size distribution measurements spread over several weeks to save on equipment costs.



How to Measure pH

Make this measurement on three samples for each horizon.

Mix Soil and Distilled Water

1. In cup or beaker, mix dried and sieved soil with distilled water in a 1:1 soil to water ratio (e.g. mix 20 g of soil with 20 mL of water, mix 50 g of soil with 50 mL of water). Mix enough soil and water so that the pH reading can be made in the *supernatant* (the clearer liquid above the settled soil particles). Use a spoon or other utensil but not your hands to transfer the soil. Oils and other materials on your hands may contaminate the pH reading. Stir with a spoon or other stirrer until the soil and water are thoroughly mixed.
2. Stir the soil-water mixture every 3 minutes for 15 minutes. After 15 minutes, allow the mixture to settle until a supernatant forms (about 5 minutes).

With pH paper (Beginning Level):

1. In a cup or beaker, measure the pH of the water you are using for this protocol by dipping the pH paper into the water and comparing the color to the color chart (as described in the *Hydrology Investigation pH Protocol*).
2. Measure the pH of the supernatant by dipping the pH paper into it (following the procedure given for pH paper in the *Hydrology Investigation*).
3. Record your results on the Soil pH Data Work Sheet.

With the pH pen or meter (Intermediate and Advanced Levels):

1. Calibrate the pH pen or meter with the buffer solutions of known pH following the procedure outlined in the *Hydrology Investigation* for Calibration.
2. In a cup or beaker, measure the pH of the water you are using for this protocol by placing the pH pen or meter into the water and reading the value indicated.

Figure SOIL-P-9

Place the bottom of the pH pen in the Supernatant (the clearer liquid above the settled soil)



The pH of this soil is 6.5

3. To measure the soil pH, place the electrode of the pH pen or meter into the supernatant. See Figure SOIL-P-9.
4. Record your results on the Soil pH Data Work Sheet.

How to Measure Soil Fertility

Part 1: Preparation and Extraction

1. Fill the extraction tube from your Soil Test kit to the 30 mL line with distilled water.
2. Add 2 *Floc-Ex* tablets. Cap the tube and mix well until both the tablets have disintegrated.
3. Remove the cap and add one heaping spoonful of soil (about 5 mL).
4. Cap the tube and shake for one minute.
5. Let the tube stand until the soil settles out (usually about 5 minutes). The clear solution above the soil will be used for the nitrate nitrogen (N), phosphorus (P), and potassium (K) tests.

Note: For some soils, especially those with a high clay content, there may not be enough clear solution extracted. If more clear solution is needed, repeat Steps 1 - 5.



Part 2: Nitrate Nitrogen (N)

1. Use the pipette to transfer the clear solution above the soil to one of the test tubes in the Soil Test Kit until the tube is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add one Nitrate WR CTA Tablet. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates.
3. Rest the test tube in a cup or beaker. Wait 5 minutes for color to develop. Do not wait longer than 10 minutes.
4. Compare the pink color of the solution to the Nitrogen Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
5. Discard the solution and wash the tube and the pipette with distilled water.
6. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 3: Phosphorus (P)

1. Use the clean pipette to transfer 25 drops of the clear solution above the soil to a clean test tube. (If there is not enough solution, repeat Part 1).
2. Fill the tube to the shoulder with distilled water.
3. Add 1 Phosphorus Tablet to the tube and cap it. Sometimes the tablets may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Mix until the tablet disintegrates.
4. Rest the test tube into a cup or beaker. Wait 5 minutes for color to develop, but no longer than 10 minutes.
5. Compare the blue color of the solution to the Phosphorus Color Chart in the Soil Test Kit. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.

6. Discard the solution and wash the tube and the pipette with distilled water.
7. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Part 4: Potassium (K)

1. Use the clean pipette to transfer the clear solution above the soil to a clean test tube until it is filled to the shoulder. (If there is not enough solution to fill the tube to the shoulder, repeat Part 1).
2. Add 1 Potassium Soil Tablet to the tube. Sometimes the tablet may break into small pieces, so be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates. Note: This tablet may take longer to dissolve than the others.
3. Compare the cloudiness of the solution in the test tube to the Potassium Color Chart in the Soil Test Kit. Hold the tube over the black boxes in the left column, and compare its shade and cloudiness to the shaded boxes in the right column. Record your results (High, Medium, Low, or None) on the Soil Fertility Data Work Sheet.
4. Discard the solution and wash the tube and the pipette with distilled water.
5. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after each use.

Data Submission

Record your data on the Bulk Density, Soil Particle Size Distribution, Soil pH, and Soil Fertility Data Work Sheets. More than one copy of a data work sheet may be required to describe a profile, so be sure to have extra copies. Staple together the sheets for the same soil profile so that records are kept together. Submit your findings to the GLOBE Student Data Server.